TETRA TECH

July 26, 2018

Ms. Mary Beth Marks, COR
USDA Forest Service
Gallatin National Forest
10 East Babcock Avenue
Bozeman, MT 59715

Subject: Beal Mountain Mine – West Wall and Clay\Sill Slide Areas
Summary of Geotechnical Review
Tetra Tech Job No. 114-560574.500

Dear Ms. Marks,

In accordance with our task order dated March 1, 2018 from the US Forest Service (USFS), Tetra Tech has completed a review of existing geotechnical reports and data regarding the Beal Main Pit high wall and leach pad embankment. This letter summarizes historic geotechnical and slope stability information, and provides an opinion on data quality, data gaps, long-term stability, and recommendations regarding additional geotechnical investigation and analysis to determine stability. The locations of inclinometers and survey prisms in relation to the slide areas, slide scarps, and other pertinent site features are shown on the attached site map (Figure 1).

Tetra Tech previously completed geotechnical field observations and monitoring at the Beal Mountain Mine site over several years (2008-2014) and provided a letter presenting the data and our conclusions following each monitoring event.

I. Slide History

There are currently two historically active slides on the Beal Mountain Mine site, the West Wall Slide and the Clay/Sill Slide. Based on historical project documents, these slides are characterized as wedge-shaped failure blocks comprised of weathered meta-sediments that move along weak clay layers (bedding plane faults) which strike between N15°W to N30°W, dipping at approximately 20 degrees to the northeast, and are bound to the northeast by the Gully Fault. The Gully Fault is a normal fault, trending N45°W, and nearly vertical to very steeply dipping to the southwest consisting of an approximately 20-foot wide zone of fault gouge.

<u>**West Wall Slide:**</u> The West Wall Slide area is also known as the Gully Fault Slide, the West Slope Failure, and the Bedding Plane No. 2 Slide in older historical documents. The West Wall Slide movement trends across and into the Beal Mountain open pit in an east-southeast direction (Figure 1). During the years of active mining (1988-1997), the slide reportedly moved on the order of 10 to 100 feet per year to the east-southeast (Sitka Corp. 1994, 1997a, 1997b). Numerous surface tension cracks occur on the flat bench in the central portion of the slide area, near survey Prism No. 8 and survey Prism Nos. 9, 10, and 11 (Figure 1). A fault-scarp with two to four feet of displacement has developed along the westernmost portion of the south flank of the

slide in response to movement. At its west end, the scar of the slide can be observed, extending up to near the main access road. A large bulge of rocky material can be observed at the toe of the slide in the north central wall of the pit above the slide plane. When last observed in 2014, a spring at the slide toe produces approximately 0.5 gallons per minute. A berm of soil, placed against the north wall of the pit to cover exposed sulfide-enriched rock, may be providing some buttressing at the toe of the slide. The 1997 *West Wall Slide Runout Analysis* report by Sitka Corp estimated slide movement to be in the range of 20 feet per year, and it was predicted the slide could move an additional 200 feet before it achieved a static state. From 2008 to 2011, the slide was documented to move at a much slower rate, with a maximum movement of approximately 19 inches measured at survey Prism No. 11 near the top of the highwall on the east side of the slide over that time (Tetra Tech, 2012b). The survey prisms have not been monitored since 2011 so the magnitude of movement at the prism locations since the last survey (July 28, 2011) is unknown.

Clay/Sill Slide: The Clay/Sill Slide is smaller in size than the West Wall Slide and is located immediately south of the southwest corner of the heap leach pad dike and to the immediate north of the West Wall Slide. The slide is bounded along its northeast flank by the Gully Fault which has a near vertical dip. In the past, this slide has raised concern with respect to the stability of the leach pad dike. Some of the previous movement observed on the Clay/Sill Slide was directly related to movement of the West Wall Slide, which through its eastward movement leaves the southern edge of the Clay/Sill Slide unsupported and allows it to move to the south-southeast. The most obvious sign of slope movement is a scarp that developed on the northern boundary of the slide during periods of significant movement (1994-1997). During the period of active mining, movement of this slide resulted in slump-like features and tension cracks upslope into the embankment fill of the southwest corner of the heap leach pad dike. A dewatering program was implemented in 1995 to decrease hydrostatic pressures and a cut and replace rockfill buttress was constructed in 1997 in an effort to mitigate the slide based on recommendations from Sitka Corp (see summary of historical documents below).

Lubrication of the slip surfaces of the West Wall and Clay\Sill Slides and hydrostatic pressures resulting from high groundwater levels within the slide mass substantially increase the likelihood and amount of movement of the slides. Historically, most movement of the slides has occurred in the spring when groundwater elevations are the highest (Sitka Corp. 1994, 1995a, 1997b).

Groundwater: Historic information to cross reference specific water level data with slide movement or hydrostatic pressures is limited. Developing a relationship between slide movement and water table elevation is difficult due to the complex geology in the clay/sill slide area, assumed differences in well construction, timing of reclamation actions, and discontinuous pumping of groundwater from selected wells. Well construction logs for six of the ten dewatering wells have been obtained. Data from 2003-2004 for the dewatering wells suggest that static groundwater elevation ranges from 7,279 (DW-4) to 7,493 (DW-6) feet above mean sea level (amsl) (15 to 222 feet below the top of casing), with an average of approximately 7,330 feet amsl (Maxim 2004).

II. Historical Geotechnical Documents

Beal Mountain Mining, Inc. (BMMI) performed several geotechnical investigations and analyses of the slide areas in the 1990's. The historical geotechnical reports available for review are listed below in chronological order with a brief summary statement.

***Draft: Interim Report, North Wall Stability Evaluation for Beal Mountain Mine Open Pit, Volume II,* Klohn Leonoff, January 19, 1990.** Provides summary of the geotechnical drilling program completed in 1989, including drill hole logs, Rock Quality Designation (RQD), core photos, inclinometer and piezometer installation, stereonet analysis, and a description of site engineering geology with respect to the North Wall of the pit at the time of publication.

***Stability Status, Gully Fault Slide, Beal Mountain Open Pit,* Seegmiller International, June 21, 1991.** Provides summary of the development and condition of the Gully Fault Slide, which developed in April/May 1991.

***Stability Evaluation, Present and Ultimate Pit Slopes, Gully Fault Slide Area, Beal Mountain Open Pit,* Seegmiller International, February 1992.** Presents stability evaluation of the Gully Fault (West Wall) Slide Area based on surface mapping of bedrock discontinuities, three core holes, and lab testing. Describes slide movement, summarizes field investigation and lab testing data, provides recommendations for remedial measures, and presents results of the stability analyses.

Summary Report: Geotechnical Core Logging, 1992 Core Holes Beal Mountain Open Pit, April 30, 1992. Presents a brief summary of core hole data from five core holes drilled in March and April 1992. Provides detailed core data, including core recovery, Rock Quality Designation (RQD), stratigraphy and physical descriptions, and point load test data,

***Stability Evaluation, Existing and Future Conditions, West Slope Failure Area, Beal Mountain Open Pit,* Seegmiller International, August 31, 1992.** Presents stability evaluation of the West Slope (Gully Fault/West Wall) Area based on previous field investigations and lab testing data, presents results of the stability analyses.

***Preliminary Assessment of Bedding Plane No. 2 Slide, Beal Mountain Open Pit,* Klohn Leonoff, April 2, 1993.** Provides summary of the Bedding Plane No. 2 (West Wall) Slide in the west wall of the pit and a preliminary stability assessment of the conditions.

***1994 Stability Evaluation, Ultimate Pit Slope – Main Beal Pit, Beal Mountain Open Pit,* Seegmiller International, March 1994.** Presents stability evaluation of the ultimate pit slope in all areas of the Main Beal Pit, including evaluation of discontinuity and strength characteristics based on nine core holes and data obtained from 1991 to 1994. Stability analyses incorporated groundwater data and evaluated potential wedge mode and rotational shear failures.

***Geotechnical Report on Beal Open Pit Extension,* Sitka Corp., July 11, 1994.** Presents a review of geotechnical aspects related to proposed deepening of the Beal open pit, including west pit wall instability and impacts of slide movements on leach pad, with recommendations for site monitoring and safety measures.

***Geotechnical Analysis of the Clay/Sill Slide, Beal Mountain Open Pit,* Sitka Corp., November 10, 1995.** Presents geotechnical analysis of the clay/sill slide in the northwest corner of the pit, including potential impacts to the existing highwall and the leach pad and evaluates various options for stabilization including a toe berm, slope layback, and leach pad push-back.

***Geotechnical Analysis of West Wall Slide Movements, Beal Mountain Open Pit,* Sitka Corp., November 30, 1995.** Presents geotechnical analysis of the west wall slide and its potential impacts on leach pad and containment dike stability, including numerical (FLAC) modeling and slope stability analyses.

***Main Beal Pit Closure, Geotechnical Review.* Sitka Corp., January 15, 1997.** Presents results of geotechnical analysis of proposed mine plan impacts on future pit wall stability, and the leach pad, and containment dike. Includes borehole geophysics data and re-assessment of geologic models of the north and west pit walls and several stability analyses.

***Geotechnical Review of Closure Options for the Main Beal Open Pit.* Sitka Corp., May 19, 1997.** Presents results of geotechnical analysis of proposed mine closure plans on future pit wall stability with respect to existing high wall stability and post-mining stabilization of the west wall and clay/sill slides, recommendations on post-operational geotechnical monitoring and ongoing dewatering. Includes compilation of information presented in previous geotechnical reports prepared by Sitka Corp from 1994-1997.

***West Wall Slide Runout Analysis.* Sitka Corp., May 19, 1997.** Presents results of geotechnical analysis and conclusions regarding the magnitude and duration of runout that can be expected if no stabilization measures are implemented.

***Proposed Raise to Heap Containment Dike, Beal Mountain Mine.* MineFill Services, Inc., April 21, 2000.** Presents results of geotechnical analysis of proposed 5-foot raise of the leach pad containment dike with respect to the clay/sill slide and leach pad stability. Based on geotechnical parameters presented in Sitka 1995 and 1997 reports. Analyses indicated the leach pad would be stable with the proposed dike raise provided dewatering program was continued. It is unknown if this raise was constructed based on review of the available project site documents.

Upon review of the above documents, the Sitka Corp reports dated May 19, 1997 represent a compilation and reevaluation of all previous relevant analyses and present a detailed stability analyses of the site representative of the conditions at the time. The material properties provided in the tables below represent the values utilized for the stability analyses presented in the 1997 Sitka Corp reports.

Table 1. Geotechnical Properties from Historic Analyses of Clay/Sill Slide (Sitka Corp. 1995a)

Material Type	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg)
Weathered Metasediments	130	0	35
Unweathered Metasediments	140	0	43
Dike Fill	130	0	35
Ore Heap	125	0	36
Cut/Replace Rockfill	130	0	35
Clay Seam	130	0	15

Table 2. Geotechnical Properties from Historic Analyses of West Wall Slide (Sitka Corp. 1997a, b, c)

Material Type	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg)
West Wall Slide Mass	130	0	35
Weathered Metasediments	130	0	35
Unweathered Metasediments	140	0	43
Altered Metasediments / Clay	130	0	10-15
Bedding Plane	130	0	13
Slide Toe	125	0	33

Table 3. Geotechnical Properties from Historic Analyses of North Highwall (Sitka Corp. 1997a)

Material Type	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg)
Weathered Metasediments	130	500	32
Unweathered Metasediments	140	12,000	40
Altered Metasediments / Clay	130	0	10-15

***Beal Mountain Mine Existing Conditions Report.* Maxim Technologies, April 2004.** Tetra Tech (previously Maxim Technologies) performed a preliminary slope stability evaluation of the clay/sill slide with respect to impacts on the leach pad. The analyses considered conditions prior to construction of the clay/sill rock buttress, conditions following buttress construction, and conditions at the time of the study, including various groundwater conditions. The analyses concluded that dewatering the clay/sill slide area with existing dewatering wells to reduce groundwater elevations has a positive impact on the factor of safety. The material properties provided in Table 4 below represent the values utilized for the stability analyses presented in the 2004 Maxim report.

Table 4. Geotechnical Properties from Analyses of Clay/Sill Slide (Maxim 2004)

Material Type	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (deg)
Unweathered Metasediments	145	0	45
Weathered Metasediments	135	0	35
Clay Seam	130	0	15
Dike Fill	130	0	35

The analyses for the clay/sill slide concluded at that time that the factor of safety for the leach pad dike will fall below the minimum factor of safety requirement of 1.5 during the spring time when the water table elevation is high (Analyses 4 and 7, Table 5). The report further concludes that should conditions similar to the worse case model develop, the clay/sill slide could regress further uphill and result in new cracks forming in the leach pad dike. The analysis results below are considered the most current and supersede previous analysis results performed by others.

Table 5. Summary of Slope Stability Analyses – Beal Mountain Mine (Maxim 2004)

Condition	Analysis No.	Comments	Factor of Safety
Pre-Buttress	1	Failure through toe of leach pad dike. Water table 30 feet below top of weathered metasediments.	1.10
	2	Failure through crest of leach pad. Same water conditions as above.	1.18
Post-Buttress	3	Failure through toe of leach pad. Same water condition as above with drainage into buttress.	1.33
	4	Failure through crest of leach pad. Same water condition as above with drainage into buttress.	1.24
	5	Failure through crest of leach pad. Weathered metasediments above clay/sill layer fully dewatered (similar to conditions during late summer/fall with dewatering program).	1.72
Current Condition	6	Water table elevation for 12/15/2003 (7,330 ft).	1.60
Worst Case Condition	7	Water table at top of weathered metasediments. Failure surface intersects dike crest.	1.02
	8	Water table at top of weathered metasediments. Failure surface intersects inboard toe of dike.	1.40

III. Recent Monitoring History

BMMI installed several slope inclinometer casings near the Clay/Sill Slide area during the 1990's to monitor slide activity. Only three of the inclinometer casings are currently functional, the remaining casings have been sheared off and/or abandoned. The three functional inclinometer casings, SI95-3, SI97-1, and SI97-2 were installed in 1995 and 1997, respectively. The baseline inclinometer survey data collected by BMMI and data from several subsequent inclinometer survey events between 1995 and 2005 was provided to Tetra Tech by the USFS.

Four optical survey targets (Prism Nos. 2 through 5) were also previously established within the Clay/Sill slide area by BMMI prior to Tetra Tech's first geotechnical monitoring event in 2008, however, we have not been provided with any historical data from these optical prism target locations for comparison to the current data. Additional optical survey targets (Prism Nos. 6 through 11) and tension crack monitoring control points were established by Tetra Tech and WWC Engineering (WWC) across the West Wall slide area in 2009 in response to our observations of new tension cracks during the 2009 annual geotechnical inspection. Prism surveys were completed by WWC in 2008, 2009, 2010, and 2011 to monitor relative movement.

Tetra Tech performed geotechnical monitoring to evaluate and document movement within the West Wall and Clay\Sill Slide areas from 2008 through 2011. Tetra Tech performed annual slope inclinometer surveys of the three functional inclinometer casings (SI95-3, SI97-1, and SI97-2) during the 2008-2011 and 2014 field seasons. Tetra Tech also obtained survey data at the stationary surface prisms and three tension crack monitoring control points located throughout the slide areas during the 2008-2011 field seasons.

Field geotechnical reconnaissance was also performed during each field season (2008-2011) to observe and document any visual evidence of slide movements. The field observations and data collected during the monitoring events was analyzed and compared with similar historical site data to determine rate and magnitude of movements. Tetra Tech provided the USFS with letter reports presenting and summarizing the data with our conclusions following each monitoring event.

Inclinometer Surveys: The active inclinometer casings are located upslope from the historical Clay/Sill Slide scarp (Figure 1). Based on review of historical site documents, the inclinometers were strategically located between the slide scarp and the toe of the leach pad embankment to document and evaluate movement indicating upslope regression of the Clay/Sill Slide area towards the southwest corner of the leach pad embankment. It should be noted that the slide area boundaries and scarp locations shown on Figure 1 are based on historical site drawings and should be considered approximate.

A summary of the inclinometer data is compiled in previous reports (Tetra Tech, 2012b; 2014), which provides both incremental data (displacement between two subsequent survey events) and cumulative data, including reference to both BMM's historical baseline data and Tetra Tech's 2008-2014 data.

Comparison of the incremental displacements at the three active inclinometer locations between the 2008 and 2010 survey events generally indicates a decreasing rate of movement during that period, followed by an increased rate of movement between the 2010 and 2011 survey events and another decrease between the 2011 and 2014 survey events. This increase in movement could be the result of many factors, including but not solely limited to the above average precipitation and snow pack over the winter of 2010-2011. The cumulative displacement between the 2008 and 2014 survey events indicates on-going creep type movement along the clay/sill slide block shear planes at SI95-3 and SI97-1, and at a slower rate at SI97-2. Some of the relative movement observed between the subsequent surveys may be considered negligible due to system accuracy and the ability to replicate exact field measurements at considerable depths.

Prism Surveys: Prism surveys were completed by WWC from 2008 to 2011 to monitor relative movement. Tetra Tech compared the survey results between the initial survey data from 2008 and 2009 to the most recent survey data in 2011. Locations of survey prisms and the general direction of overall prism movements within the slide areas are indicated on Figure 1.

A summary of the survey data is compiled in a previous report (Tetra Tech, 2012b), which provides both incremental data (displacement between two subsequent survey events) and cumulative data. The survey data indicates cumulative horizontal displacements ranging from 1.3 to 2.8 inches, and cumulative vertical displacements ranging from -2.2 to -5.9 inches (negative vertical displacement values indicate downward movement) at the Clay/Sill slide area, and cumulative horizontal displacements ranging from 9.8 to 19 inches, and vertical displacements ranging from -2.4 to -7.8 inches at the West Wall slide area. Measurements performed on crack monitor Nos. 12, 13, and 14 located near Prism Nos. 9, 10, and 11, indicate there has been 0.7 to

1.2 inches of cumulative vertical movement on opposing sides of the tension cracks at monitoring points 13 and 14.

A comparison of the relative movement measured between the surveys indicates a relatively consistent rate, direction, and magnitude of movement. Review of the data indicates that although the data appears to have a general trending direction, the data for Prism Nos. 2 through 5 is inconsistent between subsequent survey events. This inconsistency may be indicative of prism disturbance due to the general age of the prisms or possible changes resulting from freeze-thaw variance. Given the unknown age and quality of installation at Prism Nos. 2 through 5, it is possible they have been disturbed by weather conditions (frost), animals, human, or other activities. The data for Prism Nos. 6 through 11 indicates ongoing movement of the eastern edge of the West Wall Slide mass to the east/southeast between 2009 and the last survey event in 2011, which is consistent with historical slide movement.

Recent Dewatering Effort: The slide area dewatering program began in 1995 and was discontinued by BMMI in July 2003. It was reactivated in 2008 by the USFS (via Tetra Tech). Groundwater dewatering during active mining was reported to improve the stability of the slide areas. In the past 10 field seasons, dewatering wells DW-2, -3, -4, and -5 have been operated in various capacities, and periods of operation are summarized in Table 6 below. In 2018, dewatering wells DW-2 and -4 are proposed to be operated from approximately June 15 to October 15 to drawdown the water table within the slide areas. Wells DW-3 and DW-5 were not operated in 2017. Well DW-3 was not operated in 2017 as the pump would not start. Further troubleshooting was not able to identify the cause of the malfunction however the functionality of pump controls is suspect. Attempts to start Well DW-5 in 2017 were also unsuccessful. Further troubleshooting of DW-5 controls and pump indicates the submersible pump motor needs replaced. Wells DW-3 and DW-5 were not serviced in 2017 due to lack of funding.

Table 6. Summary of Dewatering Well Operation (2008-2017) – Beal Mountain Mine

Year Active	Well Nos.	Dates of Operation
2008	DW-2, -3, -4, and -5	July 1 – September 15
2009	DW-2, -3, -4, and -5	June 25 – October 30
2010	DW-2, -3, -4, and -5	June 2 – October 20
2011	DW-2, -3, -4, and -5	June 2 – October 3
2012	DW-2, -3, -4, and -5	June 21 – October 18
2013	DW-2, -3, -4, and -5	June 29 – September 25
2014	DW-2, -3, -4, and -5	May 29 – October 6
2015	DW-2, -3, -4, and -5	May 29 – October 9
2016	DW-2, -3, -4, and -5	June 15 – November 9
2017	DW-2 and -4	June 19 – October 11

IV. Summary of Key Findings

1. The *West Wall Slide Runout Analysis* (Sitka, 1997c) concluded that the West Wall Slide would self-stabilize after experiencing cumulative movement on the order of 200 ft. The approximate time period for the slide to reach equilibrium was estimated to be on the order of 20 years. Runout of the West Wall slide was also deemed to hinder any

stabilization measures at the Clay/Sill slide. It is unknown how much cumulative movement the West Wall slide has experienced since publication of the 1997 report.

2. The *Geotechnical Review of Closure Options for the Main Beal Open Pit* (Sitka, 1997b) suggested that a toe buttress on the pit floor would be the most immediate and effective means of stabilizing the West Wall slide. A cut/replace rockfill buttress along the daylight of the clay/sill seam was recommended to help stabilize the Clay/Sill slide area. The rock fill toe buttress was constructed by BMMI in late 1997 as recommended.

3. The *Beal Mountain Mine Existing Conditions Report* (Maxim, 2004) indicated that the factor of safety for the leach pad dike will fall below the minimum factor of safety requirement of 1.5 during the spring months when the water table elevation is highest. The report concluded that should conditions similar to the worse case model develop, the clay/sill slide could regress further uphill and result in new cracks forming in the leach pad dike. The analyses suggested that the instability would most likely be confined to the leach pad dike area and not regress in to the leach pad itself.

4. Comparison of the historical data, prism survey data, and the slope inclinometer data indicates on-going downslope creep type movement within both the West Wall and Clay/Sill Slide masses. The last documented period of significant movement (several feet) of the clay/sill slide occurred in 1997.

5. Surface runoff and infiltration from spring snowmelt and yearly precipitation events at the head of the West Wall Slide mass contribute to shear plane destabilization and instability, which subsequently initiates movement on the Clay/Sill Slide mass. The south road shoulder along the head of the Clay/Sill Slide area was re-graded in summer of 2012 to redirect surface runoff into a lined ditch system on the north side of the road and away from the slide areas. The topography of the West Wall Slide area appears to include a low area in the vicinity of Prism 8 (Figure 1) near the head of the slide area. This area may collect surface runoff and infiltrate into the slide area. Site grading in the southwest corner of the leach pad also collects surface runoff which drains to and pools in a low area located near the top of the slope above the West Wall and Clay/Sill Slide areas, where infiltration likely also negatively contributes to the slide area stability.

6. Dewatering wells located above the Clay/Sill Slide (Figure 1) have been operated during the past 10 summer field seasons. Since displacement measured in the inclinometers (2008-2011, 2014) and movement of the survey prisms indicated the slide planes can still be active, operation of the dewatering wells will reduce the pore pressure across the bedrock joint system below the slide mass and on the Clay/Sill Slide plane which can contribute to movement associated with the Clay/Sill Slide plane, as observed in the past.

7. Information suggests the floor of the leach pad was excavated and shaped with a ridge or internal divide within the pad from east to west and therefore, the solution volume and weight near the head of the slide area may be less than previously estimated. Repair and improvements to the existing leach pad cover system, surface diversion system, and shallow groundwater interception drain around the leach pad were completed during the 2011 construction season. The improvements to the leach pad cap system seem to have

reduced, but not eliminated, precipitation infiltration and near surface groundwater flows from collecting within the leach pad. In addition, the improvements are helping to mitigate potential slope instability associated with elevated leach pad solution levels by reducing solution recharge from groundwater and infiltration.

V. Conclusions (Data Quality, Data Gaps, Stability)

Data Quality

1. The most recent stability evaluations were performed by Sitka Corp (1997a, b, c) and Tetra Tech (Maxim 2004) based on subsurface information obtained from the historic geotechnical documents (dated 1997 or earlier). The analyses were period specific, based on surface topography and groundwater data that is now over 20 years old. The 1997 reports are considered the most comprehensive with respect to the current subsurface conditions of the Beal pit high wall and slide areas. The subsurface material properties used in the 2004 Maxim analyses were based on information provided in the 1997 Sitka reports. The subsurface material properties are within the range of values typically observed for similar materials and are considered reasonable for use as a baseline in future stability analyses.

2. While the historic stability analyses could be relied on to provide an opinion on long-term stability of the slide areas, it does not seem prudent given the uncertainties noted above when comparing the analyses to observed conditions. In Tetra Tech's opinion, reliance on 20+ year old analyses provided by others is not best practice to evaluate long-term stability or to evaluate site closure alternatives given the more powerful state-of-practice stability analysis software available, and the complex geology, groundwater conditions, slide history, and sensitive nature of the project site.

3. The cumulative displacement observed between the 2008 and 2014 inclinometer survey events indicates on-going creep type movement along the clay/sill slide block shear planes. While some of the relative movement observed between the subsequent surveys may be considered negligible due to system accuracy, it is our opinion that the data is relevant when tracked over the long-term.

4. The data for survey Prism Nos. 6 through 11 indicates on-going movement of the eastern edge of the West Wall Slide mass to the east/southeast between 2009 and the last survey event in 2011, which is consistent with historical slide movement. This data is relevant to track on-going long-term movement.

Data Gaps

5. A significant geotechnical investigation consisting of several new drill holes would be necessary to validate historic data or identify any change in geologic conditions and obtain samples for geotechnical laboratory testing to verify engineering properties and shear strength values of the various strata. The number and depth of additional drill holes necessary to perform such an investigation would be extensive and the aggregate costs

for the field investigation and laboratory testing exclusive of analysis and reporting would be expensive (on the order of $200,000-$250,000).

6. Findings from an additional geotechnical subsurface investigation and laboratory testing program may in the end be inconclusive with respect to validating currently available or historic material properties. As a result, it may not be feasible to develop final closure alternatives inclusive of mitigation alternatives for the slide area as it could prove to be economically prohibitive given the size and complex nature of the site.

7. Historic analyses of the slide areas did not evaluate stability cases inclusive of possible seismic events. The project site is located within a "seismic impact zone" which is defined by the United States Environmental Protection Agency (EPA) 40 CFR §258.14 as; *"an area with a ten percent or greater probability that the maximum horizontal acceleration…will exceed 0.10g in 250 years."* The EPA defines maximum horizontal acceleration as; *"…the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years, or the maximum expected horizontal acceleration based on a site-specific risk assessment."*

Stability

8. The previous analyses of the Clay/Sill slide area performed by Sitka in 1995 (1995a) and by Maxim in 2004 indicate that a slope failure through the leach pad containment dike is less likely, with factors of safety ranging from 1.2 to 1.4 for seasonal elevated groundwater conditions, and a marginally stable factor of safety of 1.02 at a worst-case groundwater condition at the base of the dike, which has not been historically observed. However, the on-going creep type movement observed in the slide area in the past 10 years indicates the slide mass safety factor resides much closer to marginally stable during spring months and increases as groundwater pressures dissipate. Though the rate of movement may not represent significant risk currently, the possibility of a sudden increase in movement is always present at a historically active slide area.

9. From 2008-2014, Tetra Tech has not observed significant movement of the slide areas (on the order of several feet per year) as suggested by the Sitka report (1997c), which confirms the uncertainties inherent with the mass ground movement observed and current conditions. The West Wall slide area is not considered to have reached equilibrium as indicated by recent (2008-2014) observations of on-going minor movements, yet it is also not experiencing significant movement.

VI. Recommendations

The recommendations below are developed from the conclusions above and should be considered to update the geotechnical monitoring plan, evaluate the current state of the slides, and provide long-term alternatives:

1. The RO water treatment system should continue operation annually to decrease the solution volume within the heap leach pad until a long-term leach pad cleanup alternative can be developed and implemented.

2. The last geotechnical field inspection was performed in 2011, the last inclinometer survey in 2014, and the last prism survey in 2011. A geotechnical inspection and monitoring event should be performed to review current site conditions, document any surface features indicative of slope movement, and survey the existing inclinometers and survey prisms. The purpose of this event is to reestablish the state of the two slide areas and determine the magnitude of movement within the slide areas between 2011, 2014, and 2018. In our opinion, the cost to perform this inspection and survey is relatively low in comparison to the value of having a current data set which can be evaluated to determine if future monitoring is worthwhile. The monitoring data will provide documentation of any on-going movement and justification for additional dewatering wells or mitigation efforts, if deemed necessary.

3. The area in the vicinity of Prism 8 should be reviewed for possible surface ponding and infiltration (Figure 1). Re-grading of the area to provide positive drainage away from the slide scarp towards the highwall crest should be considered. The area to the southwest of the heap leach pad where surface runoff currently drains, and pools should also be regraded to prevent surface ponding and infiltration into the head of the west wall slide area.

4. It is our opinion that the cost for a new geotechnical subsurface investigation would be better used towards performing an up-to-date geotechnical stability evaluation of the slide areas utilizing current state-of-practice analysis software, the historic subsurface data, current topography, and current groundwater elevations. The historic subsurface data can be evaluated as part of the analysis to identify which factors (such as shear strengths for the various materials, groundwater elevations, etc.) are most critical to stability. The analyses would be necessary to provide an opinion on current stability and could be used for development of long-term leach pad cleanup or stabilization alternatives.

5. The following information would be required to perform an up-to-date geotechnical stability evaluation of the slide areas: current topographical survey of slopes between the pit floor and leach pad, encompassing the lateral extents of the slide areas; and current groundwater elevations of all wells across the pit area, slide areas, and leach pad to provide an understanding of current groundwater conditions.

6. Tetra Tech reviewed the latest U.S. Geological Survey (USGS) seismic hazard map for seismic events with a 10 percent probability of exceedance in a 250-year period, as current state of practice warrants, to determine a peak spectral horizontal acceleration (PSHA) of 0.15g at the project site. Tetra Tech recommends that the slope stability evaluation include a seismic analysis to determine the factor of safety for the design seismic event.

7. The geotechnical stability evaluation should include evaluation of alternatives for re-grading the pit highwalls and slide areas for final site reclamation and closure design prior

to reintroduction to the public for access and use. Evaluating geotechnical stability of potential re-grading alternatives will determine which alternative is preferred for long-term stability during development of final site reclamation and closure plans.

8. Development and evaluation of final site reclamation and closure alternatives should prioritize leach pad cleanup, solution removal or stabilization, and/or unloading, re-grading, or pushing back the southwest area of the leach pad to prevent breach should the slide areas unexpectedly progress, or re-grading alternatives encroach on the leach pad containment dike.

Tetra Tech appreciates the opportunity to provide this service. Please contact me or Richard Dombrouski at (406) 543-3045 if you have any comments, questions, or if we can be of further service.

Sincerely,

TETRA TECH

MONTANA
7/26/2020
JEREMY
DIERKING
No. 15692 PE
LICENSED
PROFESSIONAL ENGINEER

Jeremy Dierking, P.E.
Project Geotechnical Engineer

Attachments:
Figure 1 – Site Map

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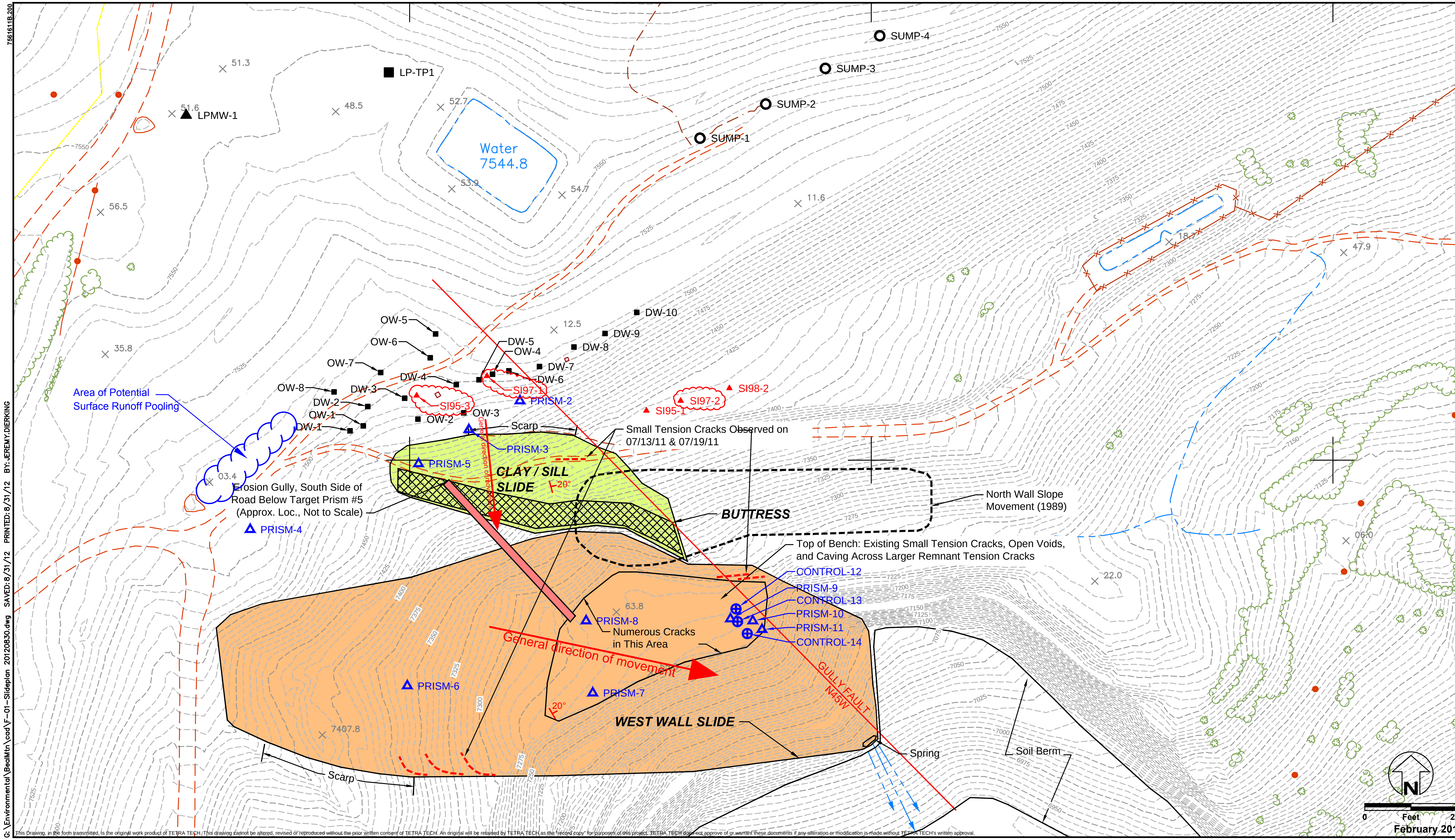

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OW-7 ■ Dewatering or Observation Well
SI95-3 ▲ Geotechnical Slope Inclinometers (Active)
△ Geotechnical Prisms
⊕ Geotechnical Crack Monitoring Controls
Spring Flow
Tension Cracks

Main Beal Pit Slides
Beal Mountain Mine
Silver Bow County, Montana
FIGURE 1